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COMPARISONS OF WING PRESSURE DISTRIBUTION FROM FLIGHT TESTS OF FLUSH AND EXTERNAL ORIFICES FOR MACH NUMBERS FROM 0.50 TO 0.97

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INTRODUCTION

Measurements of wing pressure distributions have long been used to evaluate the properties of airfoils. These pressure distributions have been obtained mainly by using flush static orifices. In some instances where installation difficulties, or cost, prohibited the use of flush static orifice installations, a simpler and less expensive method was used. This method consisted of attaching flexible tubes or banks of tubes external to the wing surface with the static orifices spaced along the tubing. With this type of external installation, the validity of the pressure measurement is questionable because of possible effects of the tubing on the local flow characteristics. Previous experimental data for external installations, such as those in references 1 to 6, are limited, which precludes direct comparisons between flush and external static orifice installations for similar test conditions in flight.

In this paper direct comparisons are made between wing pressure distributions obtained in flight with flush and external tubing orifices at three spanwise stations. The orifice locations were identical on both the upper and lower wing surfaces at each span station for the two types of installations.

The external tubing was used mainly to simulate an external orifice installation, and the pressures obtained with the external tubing were actually transmitted through the same plumbing as had been used with the flush orifices. The flight tests covered an angle-of-attack range of approximately 2.0° to 6.0° for Mach numbers of 0.90 and 0.97, and an angle of attack of approximately 5° for a Mach number of 0.50. The external tubing had an outside diameter of 0.476 centimeter (0.187 inch) and an inside diameter of 0.244 centimeter (0.096 inch) and consisted of a bank of 10 tubes. All data were obtained at a dynamic pressure of approximately 9.6 kN/m^2 (200 lb/ft^2).

The procedure for installing the external tubing and problems encountered during installation are discussed.

SYMBOLS

Physical quantities in this report are given in the International System of Units (SI) and parenthetically in U.S. Customary Units. Factors relating the two systems are presented in reference 7.

C_p pressure coefficient, $\dfrac{p - p_\infty}{q}$

c local wing chord

c_n section normal-force coefficient, $\displaystyle\int_{\substack{\text{Leading}\\\text{edge}}}^{\substack{\text{Trailing}\\\text{edge}}} \left(C_{p_{lower}} - C_{p_{upper}}\right) dx/c$

M free-stream Mach number

p local static pressure, kN/m^2 (lb/ft^2)

p_∞ free-stream static pressure, kN/m^2 (lb/ft^2)

q free-stream dynamic pressure, kN/m^2 (lb/ft^2)

x chordwise distance rearward of leading edge, cm (in.)

α corrected airplane angle of attack, deg

TEST VEHICLE AND INSTRUMENTATION

The tests were made on a NASA research airplane consisting of a Navy TF-8A fuselage and empennage fitted with a NASA supercritical wing (fig. 1). Pressure distribution measurements were obtained on the right wing at the three semispan stations shown in figure 2.

The wing pressures were measured with scanivalves which were located in instrument bays as shown in figure 2.[a] These locations were chosen so that the scanivalves could be as close to the orifice rows as possible. Differential pressure transducers were used with all the scanivalves and were connected to the same reference source (fig. 2). The reference source was in a compartment in the fuselage behind the cockpit and was monitored with absolute pressure cells.

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[a]*During this study the scanivalve which measured pressures on the aft portion of the upper surface and the entire lower surface pressures of row 2 was inoperative, thus no data are presented for these areas.*

Free-stream conditions were obtained from the airplane's airspeed system which consisted of a compensated airspeed head and precision transducers in the nose of the airplane. This system was calibrated in flight for residual position error by techniques described in reference 8.

Orifice Installations

Flush static orifices.—The flush static orifices were installed during the wing construction. They consisted of 0.318 centimeter (0.125 inch) inside diameter stainless steel tubing and were mounted flush with the wing surface to within ±0.0025 centimeter (±0.001 inch). All the orifices were installed normal to the wing surface and had "square," burr-free edges.

External tubing.—Before the external tubing was installed, the wing surface was thoroughly cleaned with a solvent. Because the wing had been painted and the paint was still in good condition, this procedure was considered adequate for the purposes of this study.

The external tubing consisted of a 10-tube bank of plastic tubing of 0.244 centimeter (0.096 inch) inside diameter and 0.476 centimeter (0.187 inch) outside diameter. The tubing was precut to the desired lengths; separate lines were used for the upper and lower surfaces. The tubing extended partially around the wing leading edge, as shown in figure 3. The orifices were then drilled completely through both sides of the external tubing (fig. 4) such that each orifice through the external tubing was directly over a corresponding flush static orifice. At the center semispan location, another section of external tubing was installed inboard and adjacent to the first section (fig. 5) to detect possible effects on the pressure distribution caused by the differences in width of the external tubing sections.

A potting compound was then applied to areas which had been marked by the outside edges of the external tubing, leaving a small area around the flush static orifices without potting compound.

The external tubing and flush orifices were lined up with pins, which were of the same diameter as the orifice holes. The tubing was then pressed down and held in place with tape to allow the potting compound to set.

After the potting compound was set, holes were drilled in front of and behind the orifice locations (fig. 4) so that plugs could be inserted. The plugs, which were made of the potting compound, were used to isolate each orifice from the others in the common (fifth) tube that was used for all the orifices.[a]

The leading and trailing edges of the external tubing were cut at an angle and faired with potting compound, as shown in figure 3 for a leading edge. The sides of the external tubing were also faired using potting compound (figs. 3 and 4).

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[a]*This is also done where orifices are drilled on separate tubes to isolate the unused tubing for lag and leak purposes.*

External Tubing Problems

Orifice cutter.—The problem of drilling round, burr-free holes with "square" edges was solved by using a special cutter (fig. 6). The cutter consisted of a rod with a hole through its center and slightly tapered sides, which gave it a sharp edge. The untapered end of the cutter was held in a pin vise which served as a handle. The holes were drilled in the tubing by rotating the cutter. To increase its life, the cutter was oil hardened.

Bonding.—In the first attempt to attach the external tubing to the wing, a cement was used which did not adhere to the surface because the tubing was stretched and did not lie flat on the surface when the orifices were lined up with the pins. An alternate bonding agent, a potting compound, was then used and was found to bond well because it filled the loose areas between the tubing and the wing surface. The potting compound was also much easier to work with than the cement and did not have to be applied to the entire area under the external tubing (light areas under the tubing, fig. 4).

Fairing.—In fairing the edges of the external tubing, it was difficult to get a smooth surface when using the potting compound. This difficulty was alleviated by adding a small amount of oil to the spreading tool, which prevented the potting compound from sticking and dragging when spread along the edges.

RESULTS

Representative wing chordwise pressure coefficients obtained in this study from the external tubing and flush orifices are presented in figures 7 to 9. These data are for Mach numbers of 0.50, 0.90, and 0.97 and several angles of attack. The data are evaluated only to the extent of the agreement or disparity in the results from the two types of orifices.

The results for the flush orifices and external tubing orifices agree for the most part, though there are some differences. The largest differences are at $M = 0.90$ and $\alpha = 6.37^\circ$ (fig. 8(c)) where the flow was known from earlier wind-tunnel tests to be highly sensitive to small changes in angle of attack or Mach number. It is believed that the external tubing may have accentuated this effect at these test conditions.

The external tubing orifice results generally tend to be slightly more negative for both the upper and lower surfaces at the two highest Mach numbers. These more negative pressure coefficients are considered to be due mainly to the increased wing thickness resulting from the external tubing size and the manner in which the external tubing was faired into the leading edge (fig. 3).

As mentioned earlier, row 2 had an additional bank of external tubing inboard of the actual pressure measuring orifices to check for possible effects on the pressure measurements of spanwise flow. In figures 7 to 9 it can be seen in general that the data for row 2 agree as well with the flush orifice results as the data for rows 1 and 3.

It should be noted that the external tubing size relative to the wing section maximum thickness increased from 4.1 percent at row 1 to 11.3 percent at row 3. Because of this increase, it was expected that effects of the external tubing would become most significant on the outboard wing sections, particularly at the highest Mach numbers. Yet the data for all three rows show similar agreement with the flush orifice results.

Figure 10 presents the section normal-force coefficients for rows 1 and 3 obtained by integrating the pressure coefficients of figures 7 to 9. These data show that the section normal-force coefficients obtained from the external tubing orifice pressure coefficients were approximately 10 percent higher than those from the flush orifice pressure coefficients. This difference is believed to be due to the change in airfoil contour after the external tubing was added, although the fairing of the external tubing along the leading edges and sides may also be a factor. Thus pressure measurements made with external tubing could probably be improved by using smaller size tubing and extending the installation fairings.

CONCLUDING REMARKS

A direct comparison of wing pressure coefficients obtained from flush and external tubing static orifices at three wing stations and Mach numbers of 0.50, 0.90, and 0.97 indicates that an external orifice installation can give useful results.

In general the two methods of measurement show similar wing pressure coefficients. The external tubing orifice pressure coefficients were generally slightly more negative at the two highest Mach numbers. This was considered to be due mainly to the increased wing thickness resulting from the tubing size, and the method of fairing the external tubing at the leading edges.

The addition of a second bank of tubes inboard of the actual measuring orifices did not affect the results.

The section normal-force coefficients obtained from the external tubing installation pressure coefficients were approximately 10 percent higher than those obtained from the flush orifice pressure coefficients. The higher coefficients for the external tubing orifices were probably due to the change in wing contour.

The results of the study suggest that additional studies be made to evaluate the effects of external tubing size and methods of installation.

Flight Research Center
National Aeronautics and Space Administration
Edwards, Calif., April 16, 1975

REFERENCES

1. Browne, G. C.; Bateman, T. E. B.; Pavitt, M.; and Haines, A. B.: A Comparison of Wing Pressure Distributions Measured in Flight and on a Wind Tunnel Model of the Super VC.10. R. & M. No. 3707, British A.R.C., Nov. 1971.

2. Grant, R.: Strip-A-Tube Tubing Response Characteristics. Instrumentation Development Lab. Rep. 7004, McDonnell Co., Feb. 20, 1970.

3. Wages, N. G.: F-4 Flight Test Investigation of Transonic Scaling. Vol. 1. MDC A0902, McDonnell Aircraft Co., Apr. 1, 1971.

4. Haines, A. B.: Possibilities for Scale Effect on Swept Wings at High Subsonic Speeds: Recent Evidence From Pressure Plotting Tests. Facilities and Techniques for Aerodynamic Testing at Transonic Speeds and High Reynolds Number. AGARD-CP-83, 1971.

5. McIntosh, J. F.: Measurement of Wing Surface Static Pressure Distribution Using External Multibore Polyvinyl Tubing. W.T. Rep. 2468, B.A.C. Weybridge, Mar. 1962.

6. Port, W. G. A.; and Morrall, J. C.: Flight Tests of a Simple Method of Measuring Pressure Distributions on a Wing. Tech. Note No. Aero 2583, Royal Aircraft Establishment (Bedford), Sept. 1958.

7. Mechtly, E. A.: The International System of Units—Physical Constants and Conversion Factors. Second Revision. NASA SP-7012, 1973.

8. Webb, Lannie D.; and Washington, Harold P.: Flight Calibration of Compensated and Uncompensated Pitot-Static Airspeed Probes and Application of the Probes to Supersonic Cruise Vehicles. NASA TN D-6827, 1972.

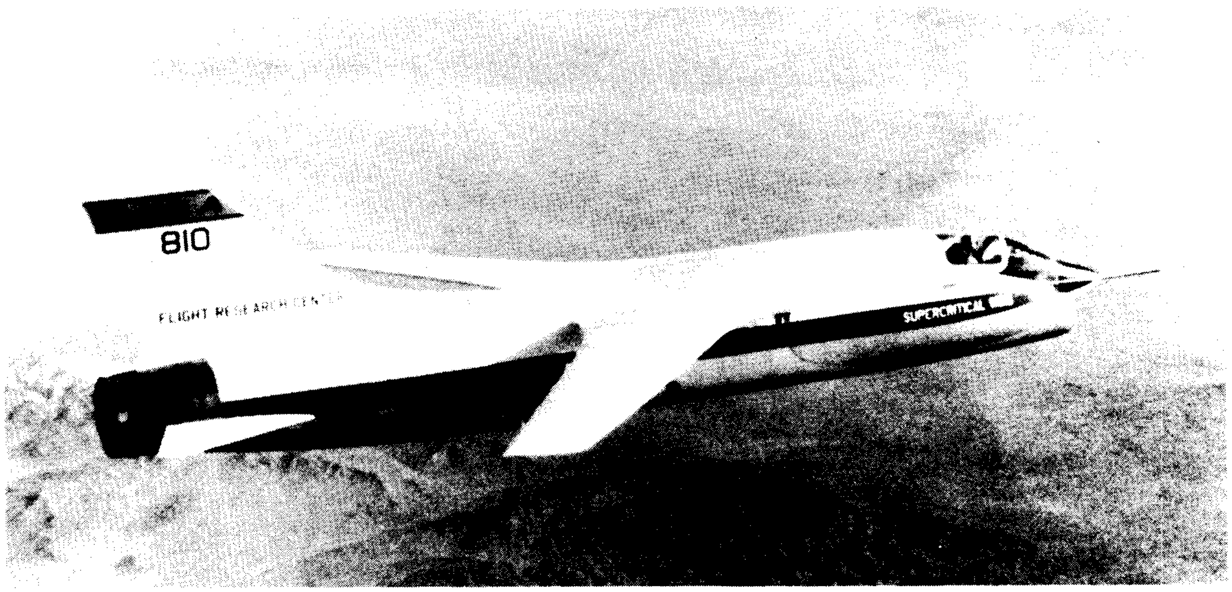


Figure 1. Supercritical wing research airplane in flight. *E-26016*

Row	Span station	Percent semispan
1	79.4	0.306
2	169.0	0.653
3	241.5	0.933

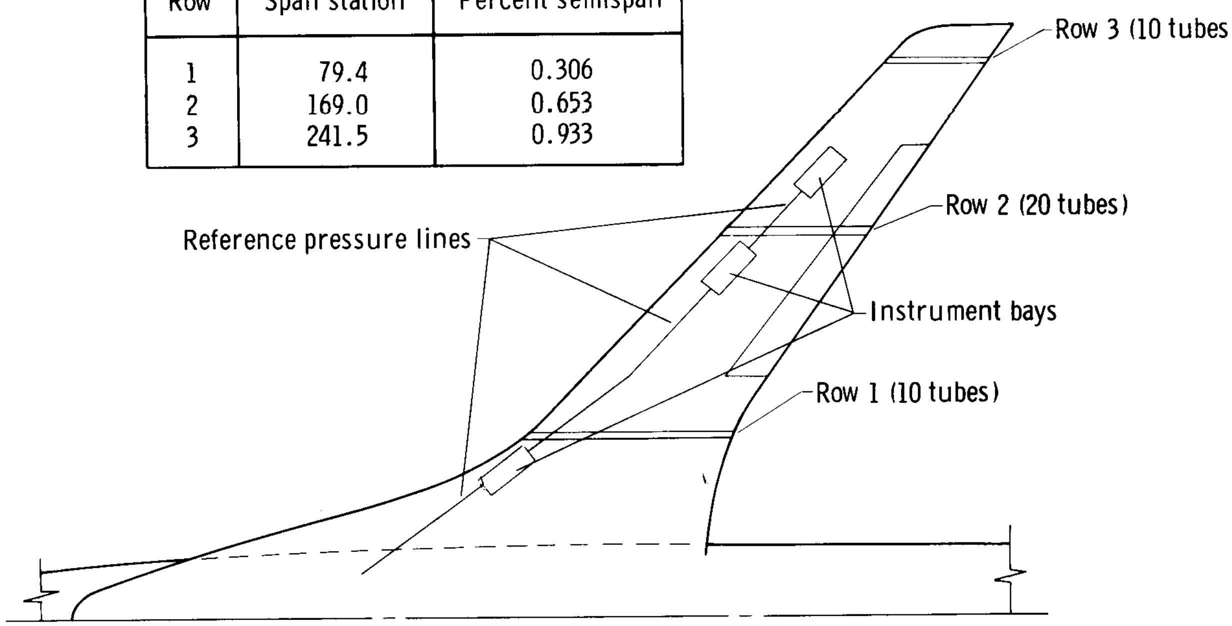


Figure 2. Sketch showing the location of the pressure measuring stations and instrument bays.

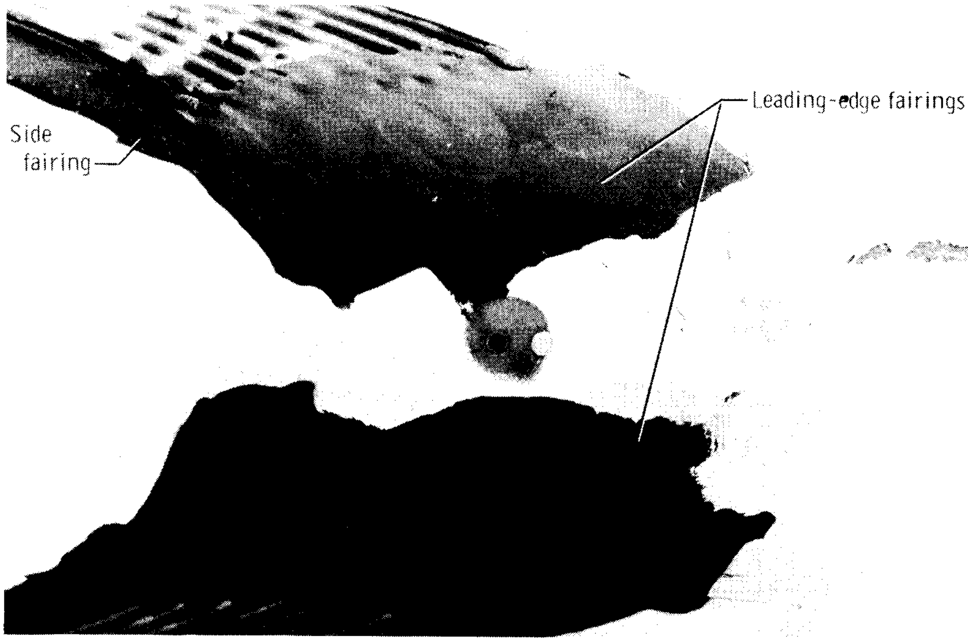


Figure 3. External tubing installation near the leading edge. *E-25817*

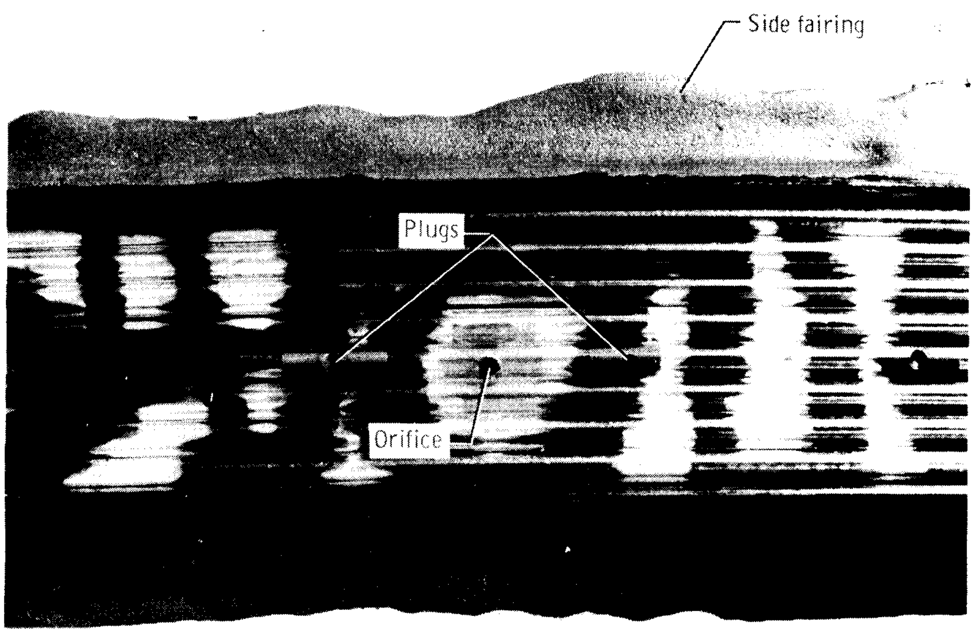


Figure 4. Typical external tubing installation with the drilled static orifice and plugs. *E-25819*

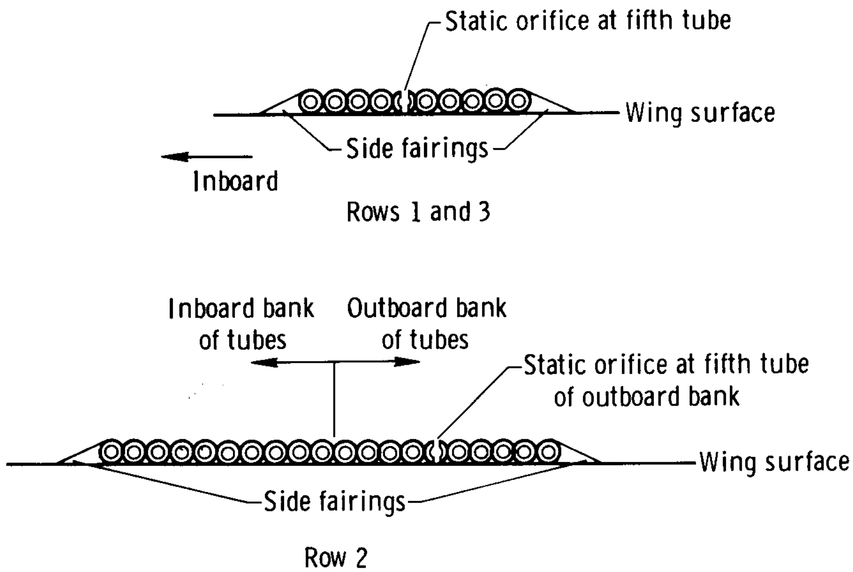


Figure 5. Sketch showing cross sections of the external tubing orifice installation.

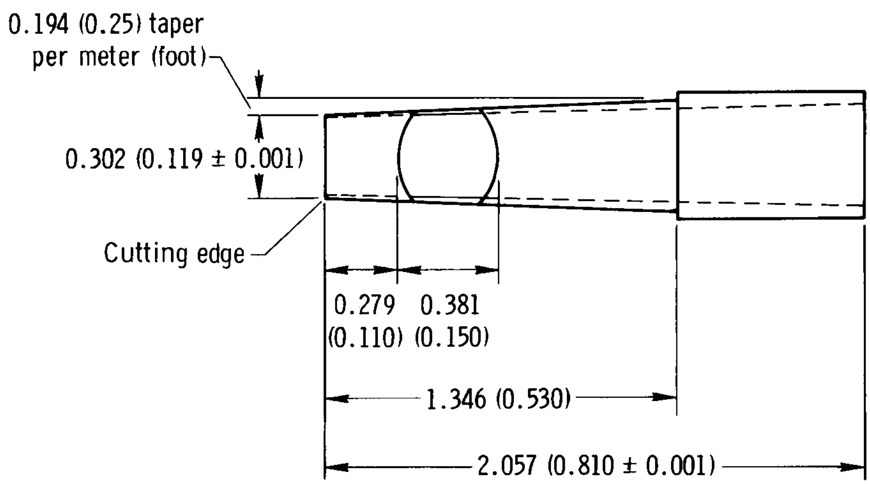
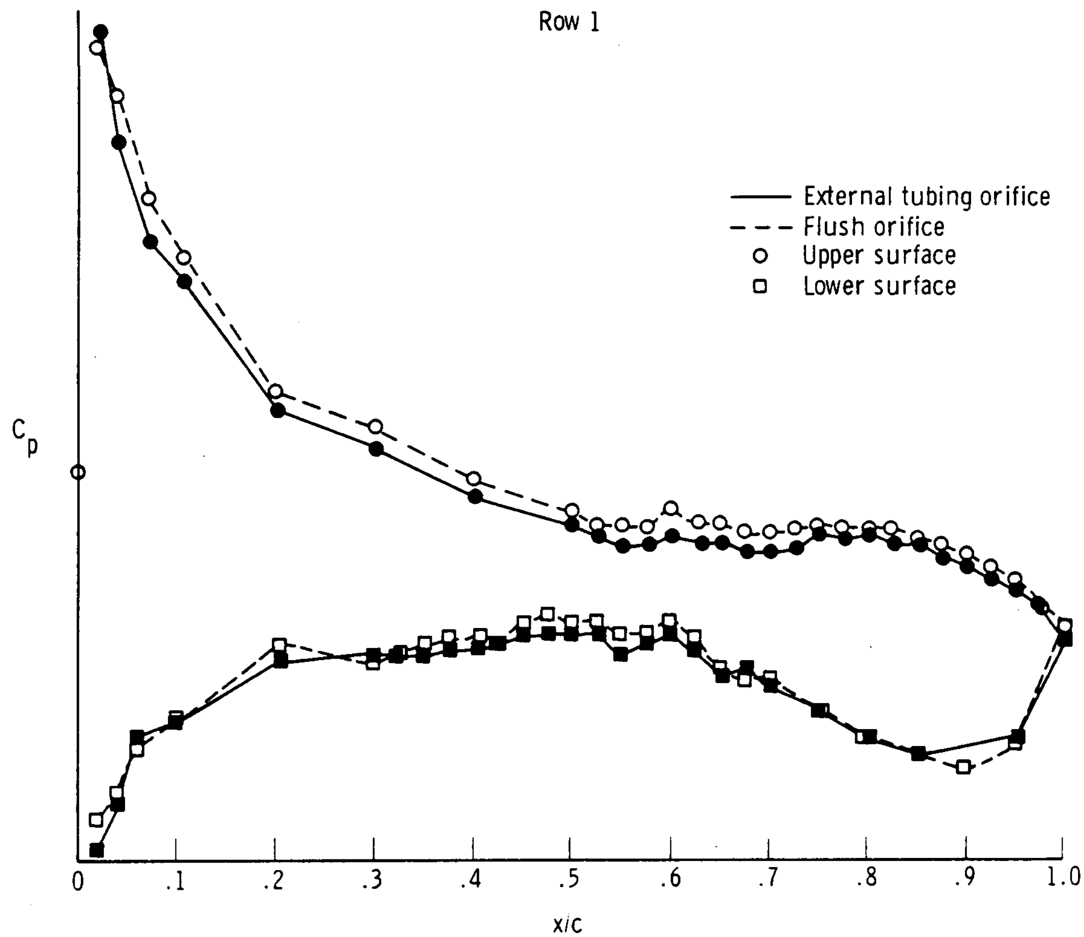
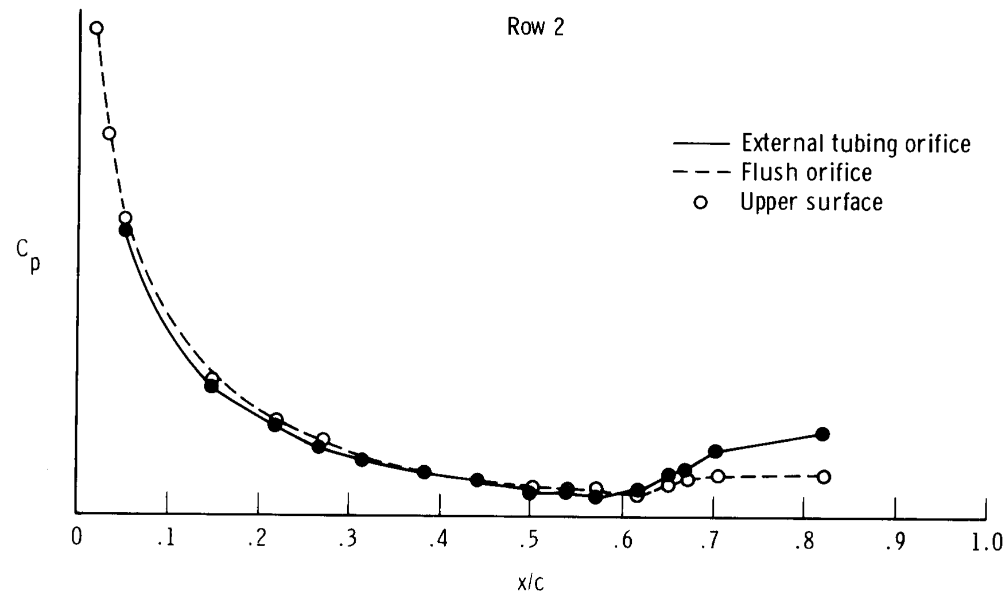


Figure 6. Sketch of the external tubing static orifice cutter. Dimensions in centimeters (feet).

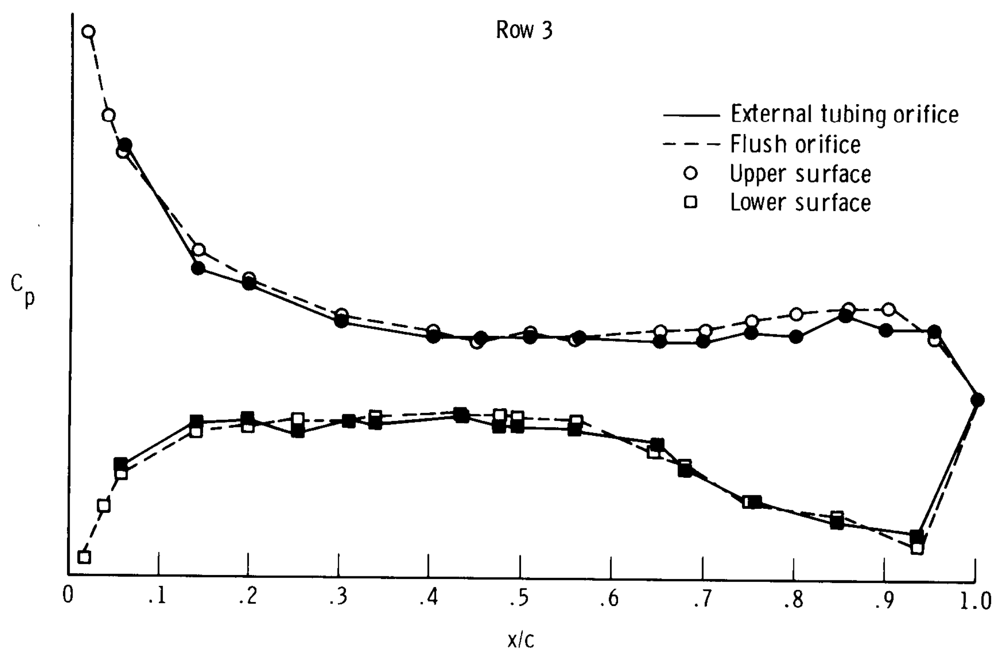


(a)

Figure 7. Chordwise pressure distribution at a Mach number of 0.50 and an angle of attack of 5.27°.

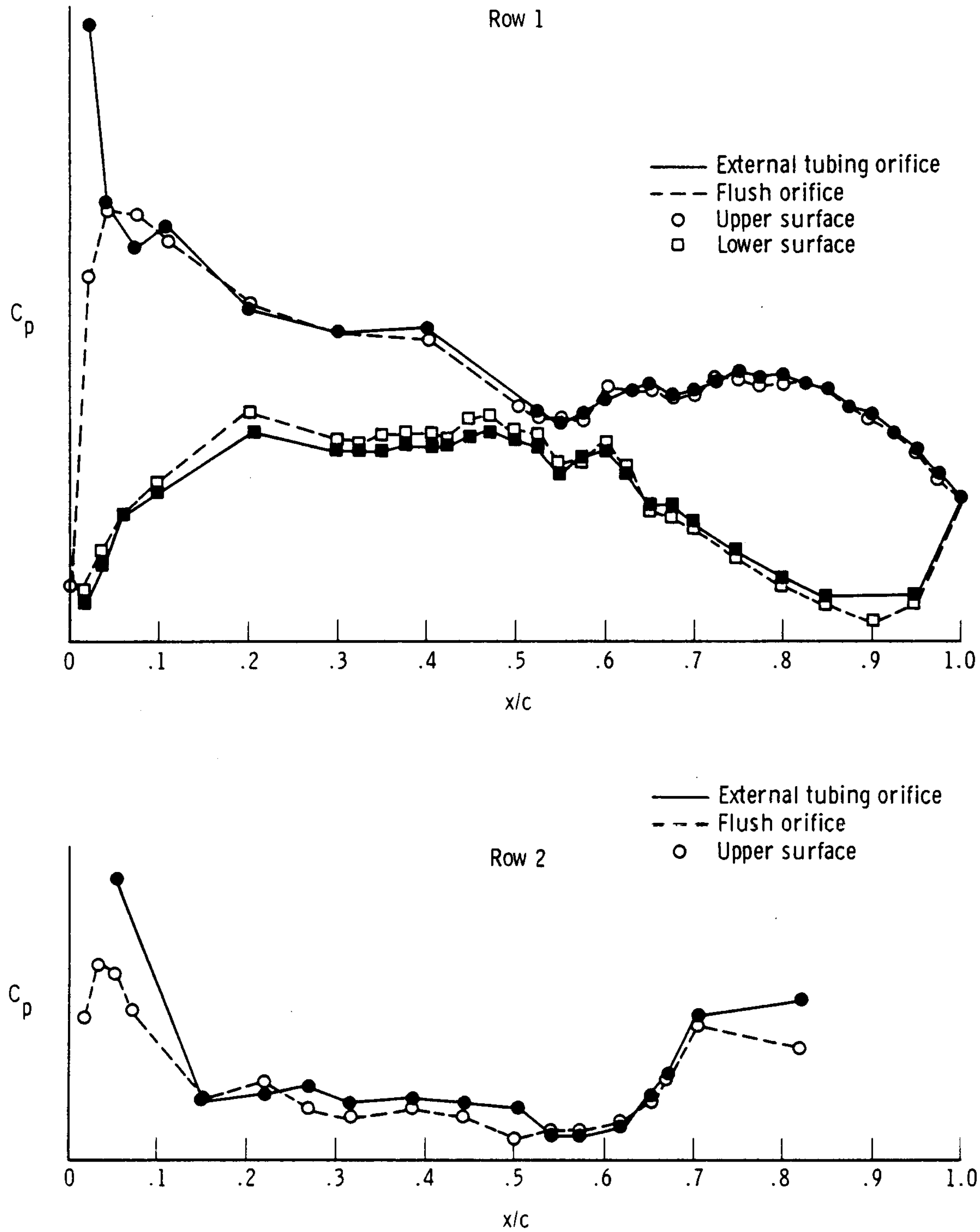


(b)



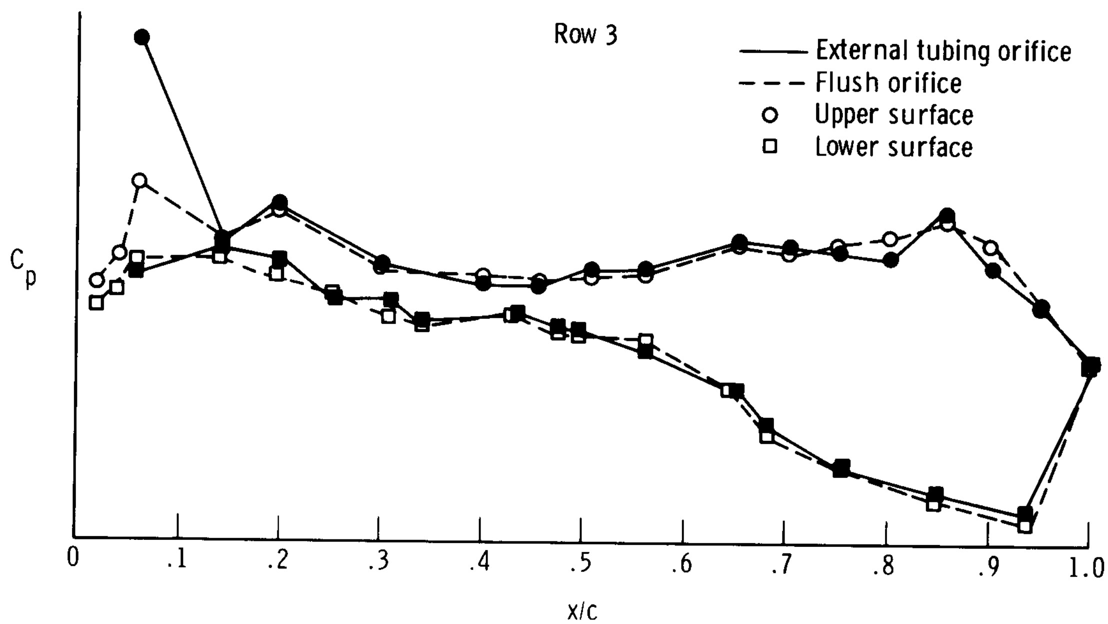
(c)

Figure 7. Concluded.



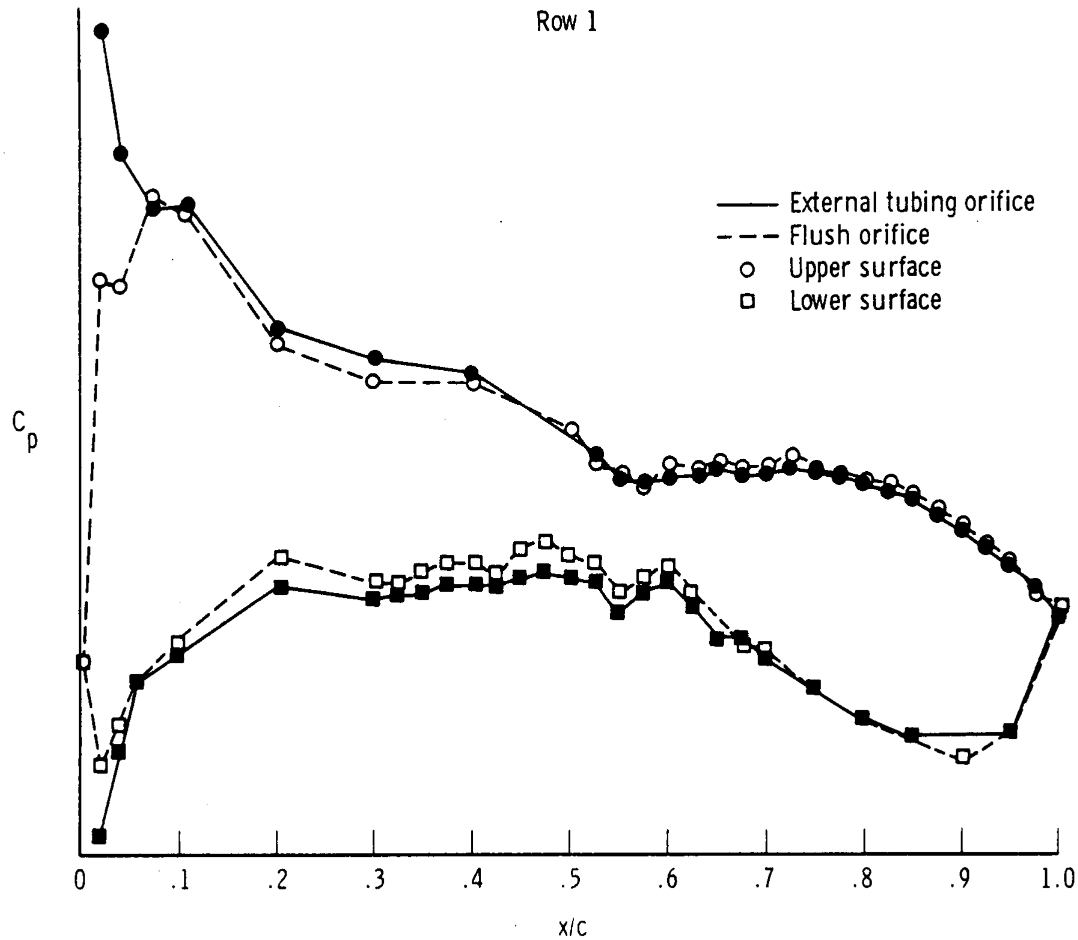
(a) $\alpha = 2.30°$.

Figure 8. Chordwise pressure distribution at a Mach number of 0.90 and angles of attack of 2.30°, 4.00°, and 6.37°.



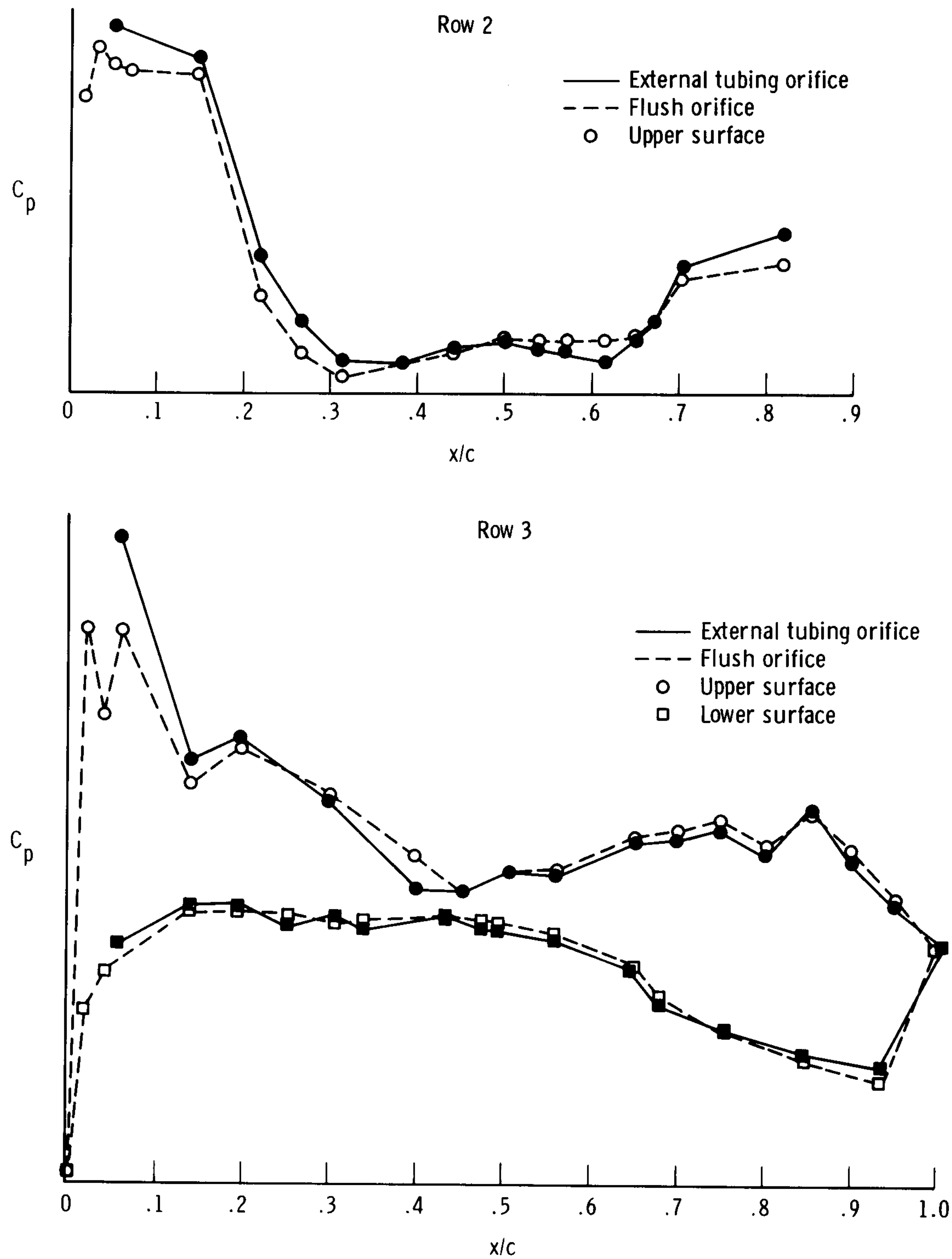
(a) Concluded.

Figure 8. Continued.



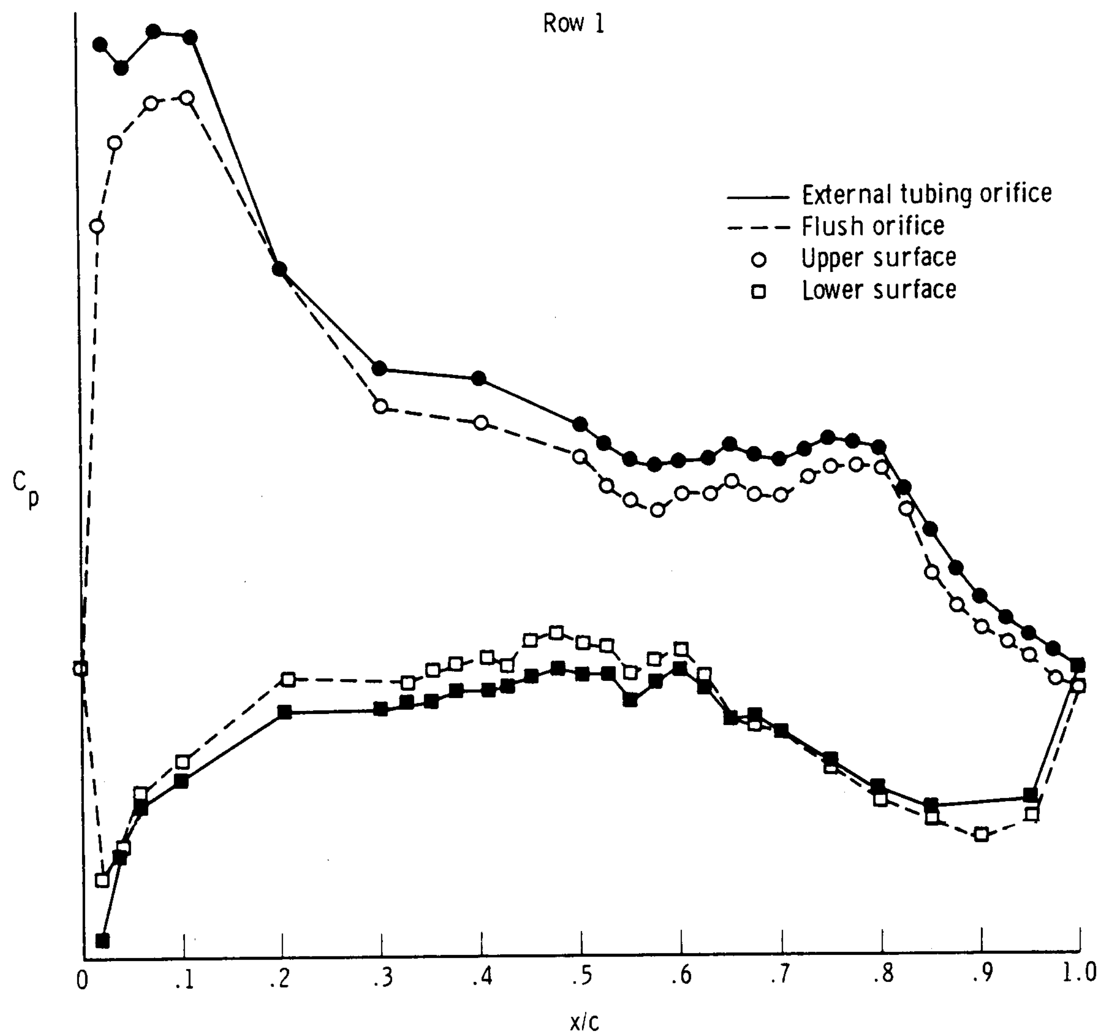
(b) α = 4.00°.

Figure 8. Continued.



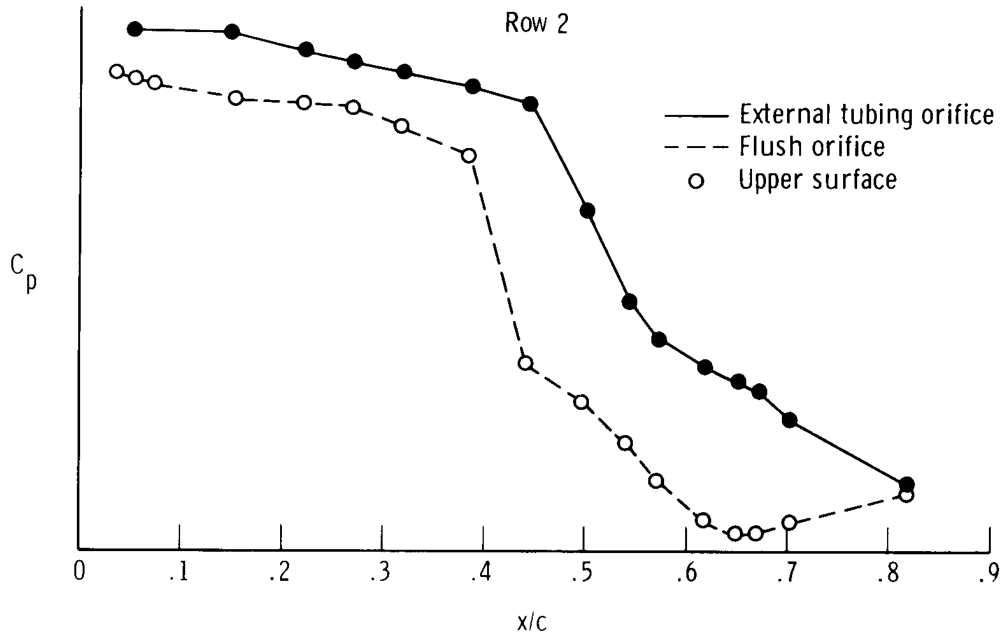
(b) Concluded.

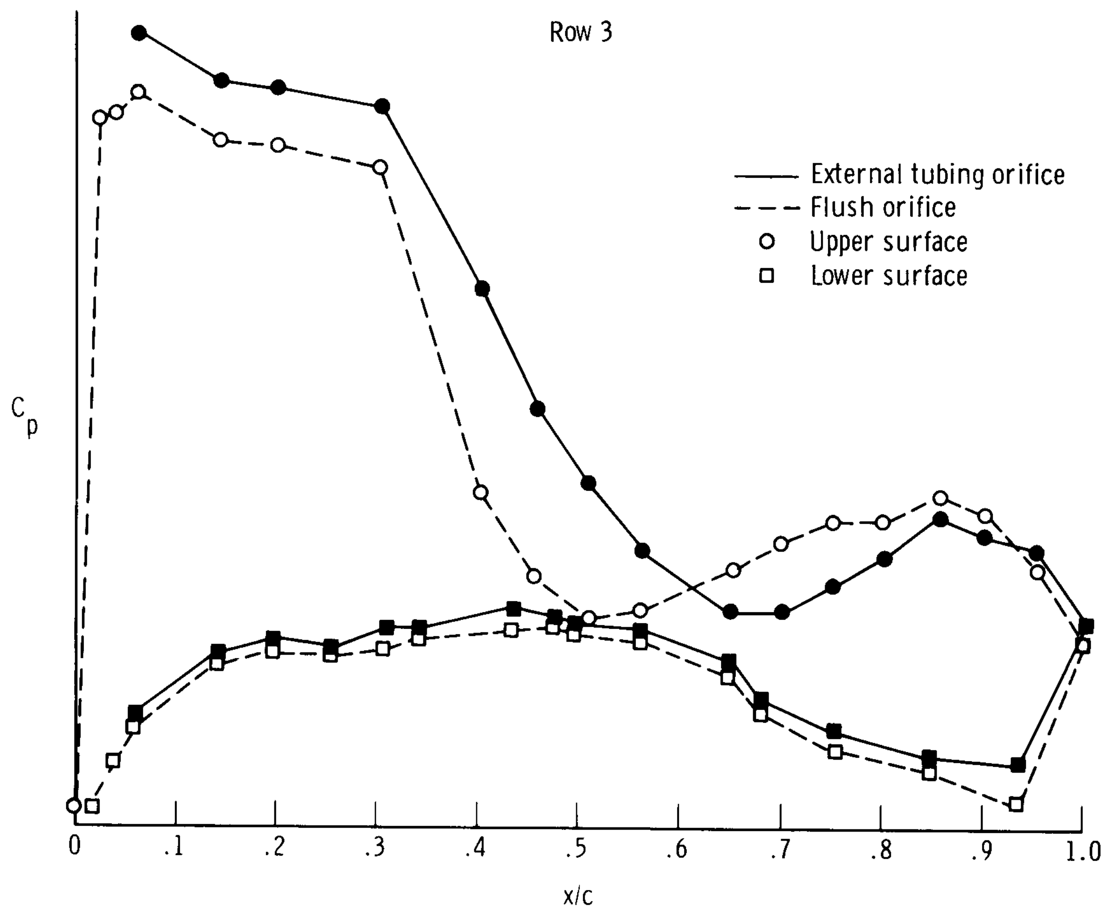
Figure 8. Continued.



(c) $\alpha = 6.37°$.

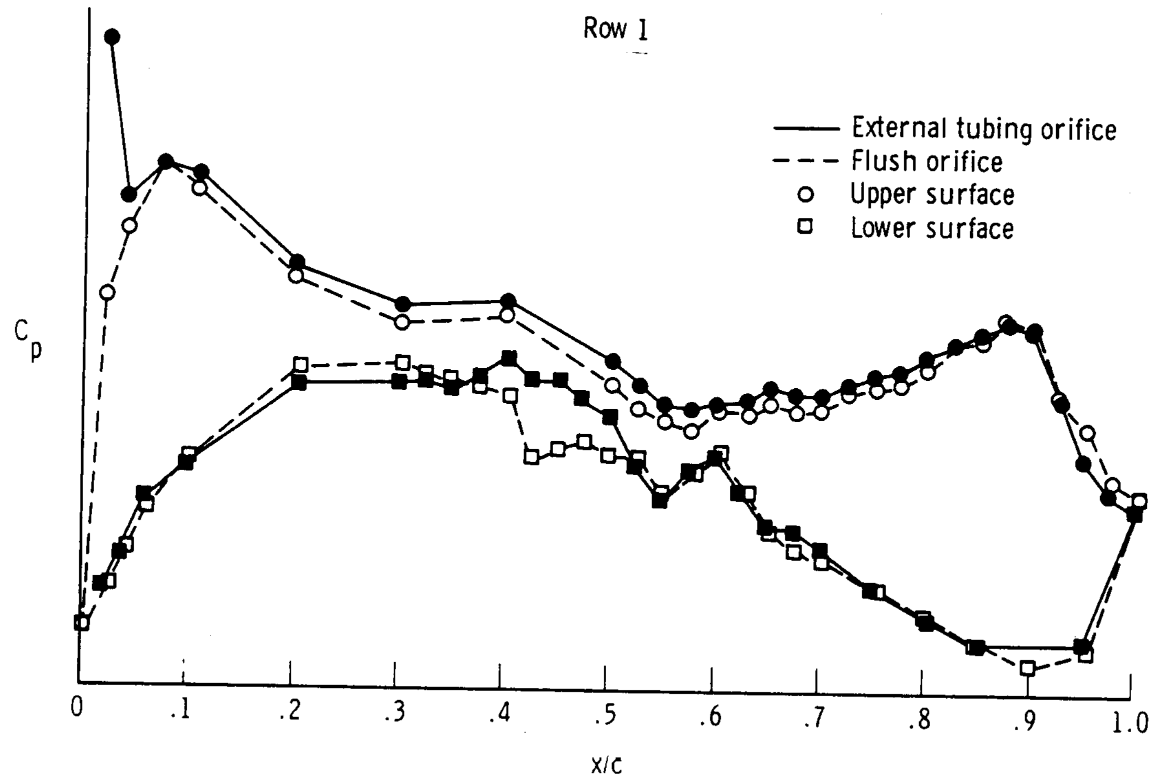
Figure 8. Continued.





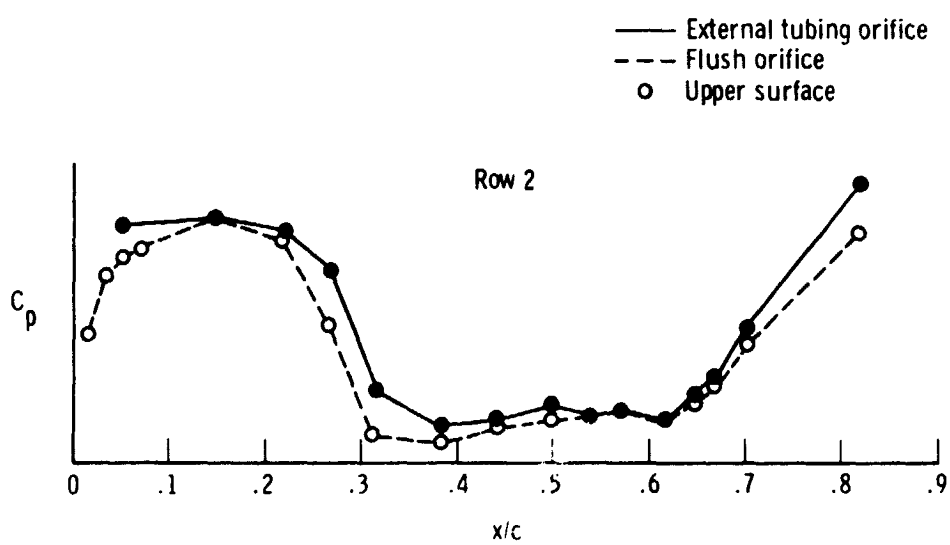
(c) Concluded.

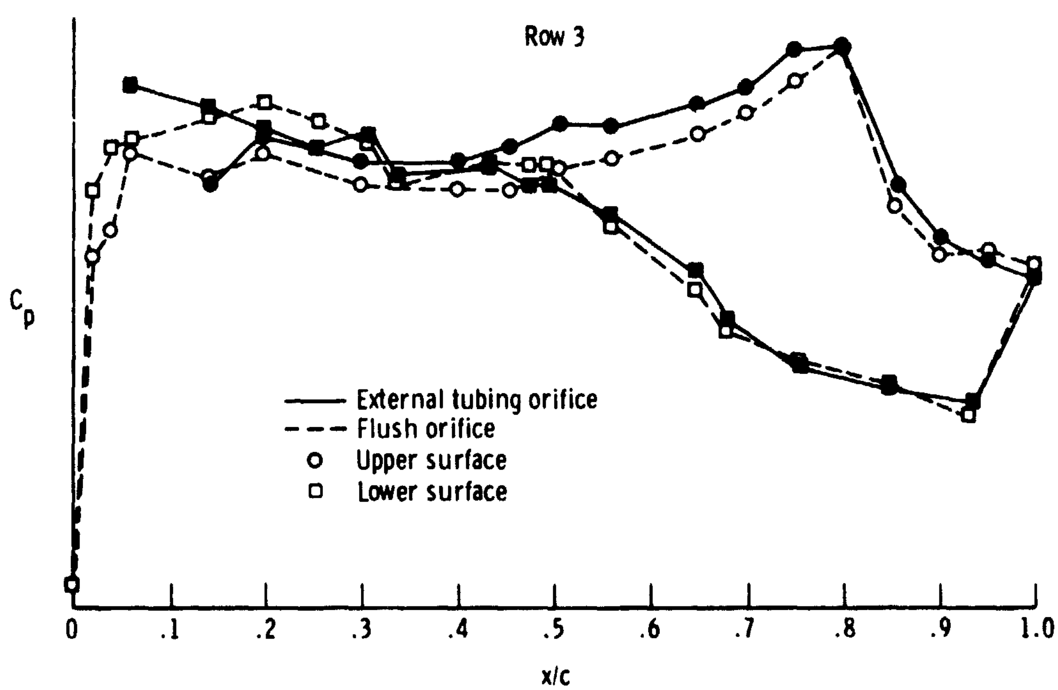
Figure 8. Concluded.



(a) $\alpha = 2.30°$.

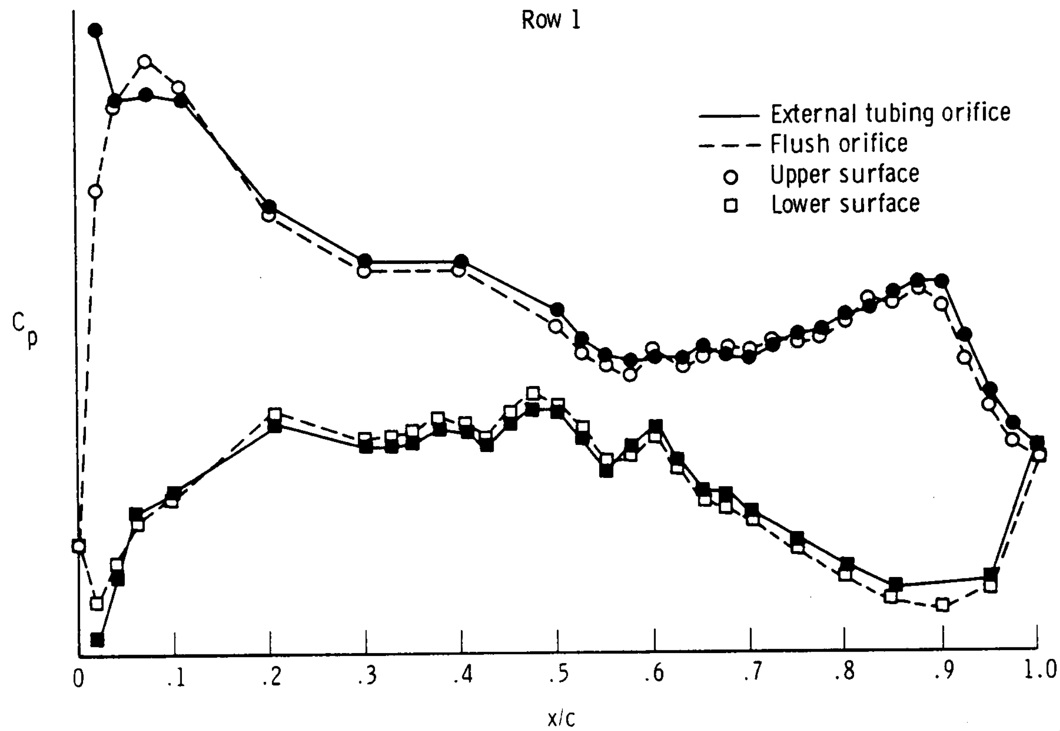
Figure 9. Chordwise pressure distribution at a Mach number of 0.97 and angles of attack of 2.30°, 3.72°, and 6.25°.





(a) Concluded.

Figure 9. Continued.



(b) $\alpha = 3.72°$.

Figure 9. Continued.

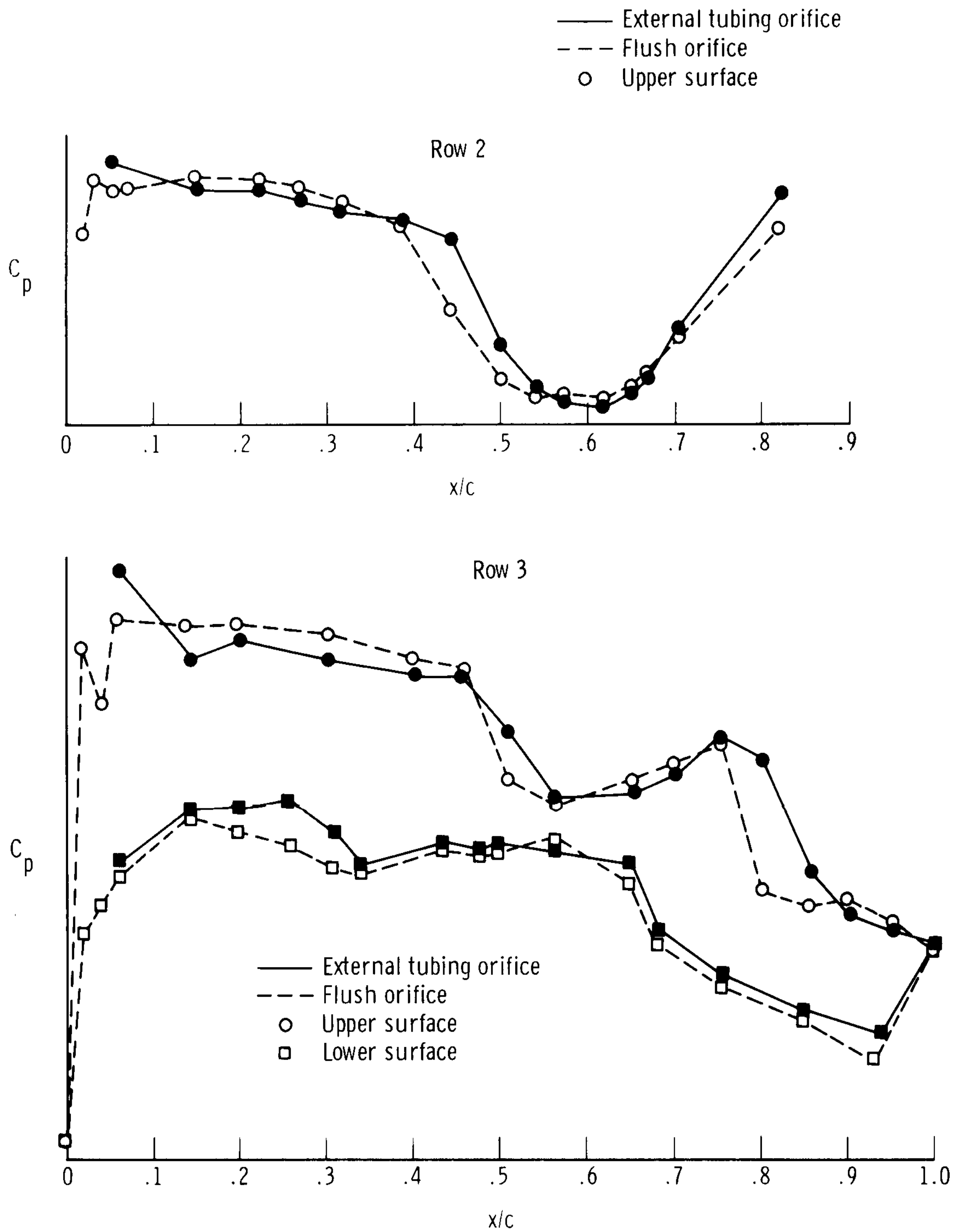


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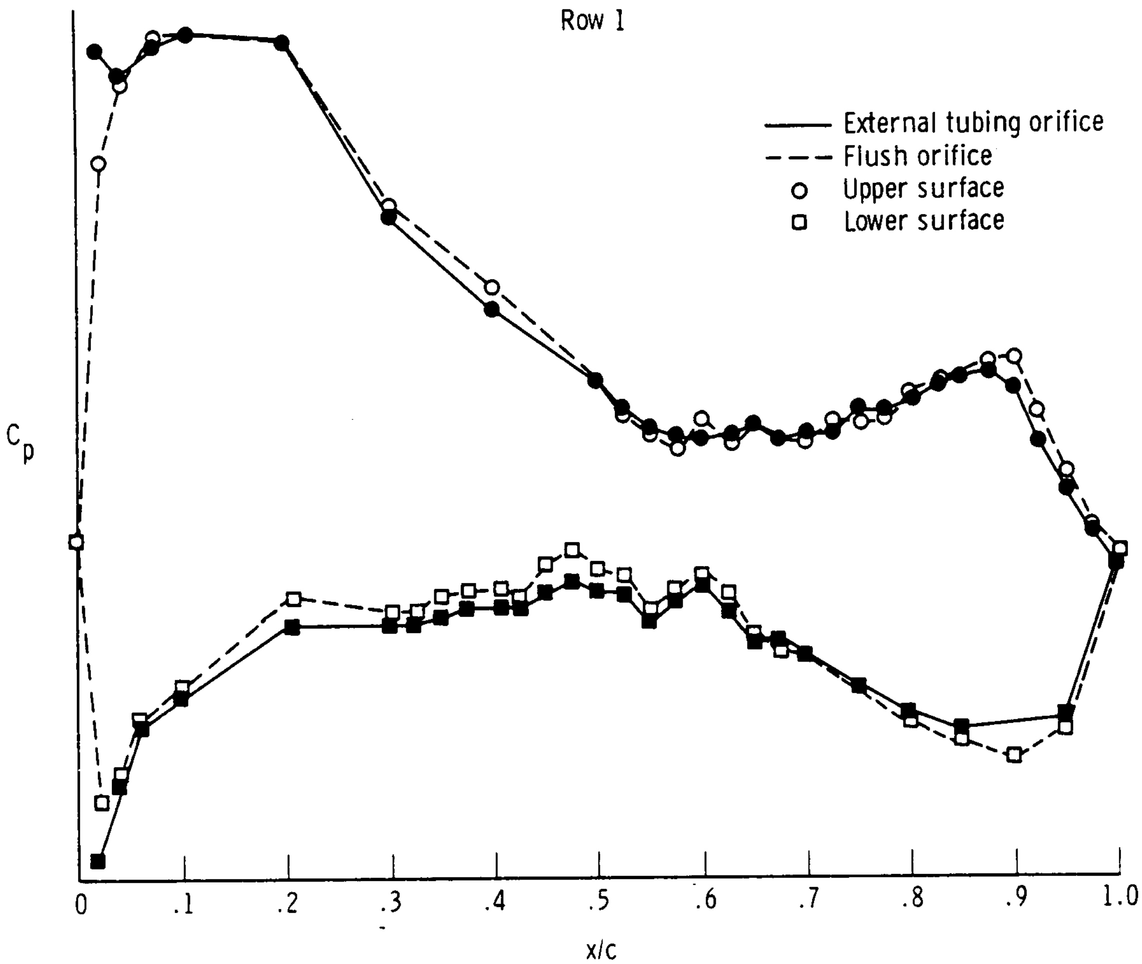
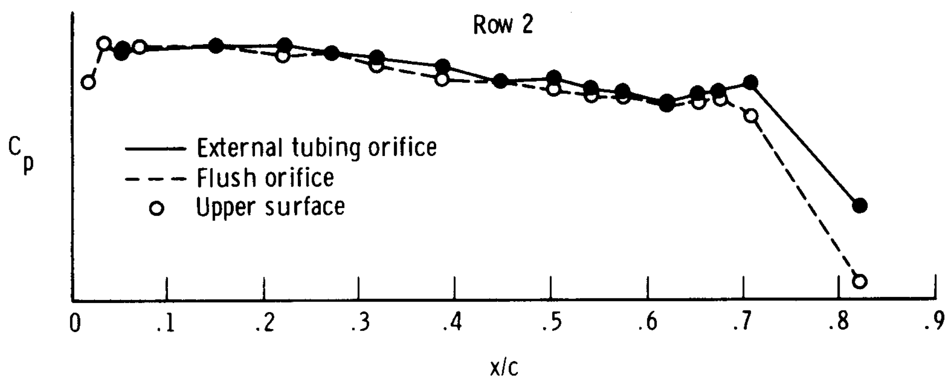
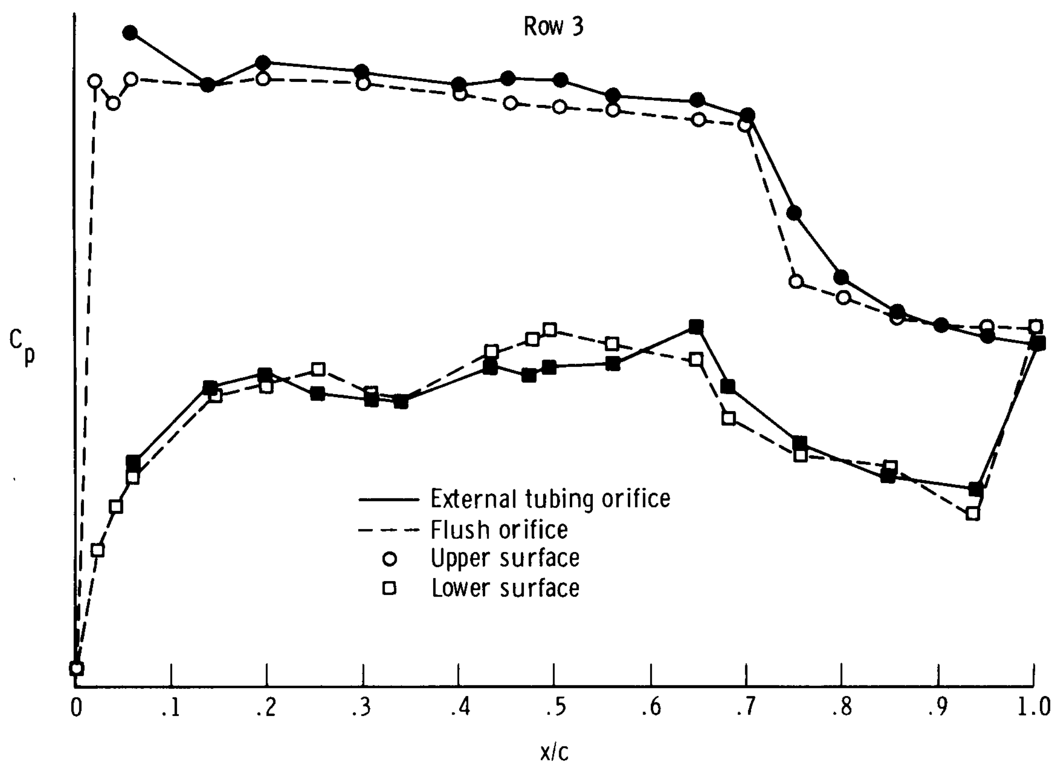
Figure 9. Continued.



(c) α = 6.25°.

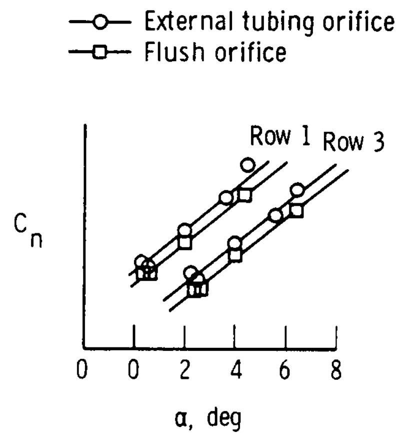
Figure 9. Continued.



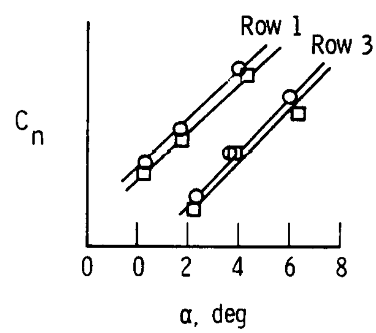


(c) Concluded.

Figure 9. Concluded.



(a) M = 0.90.



(b) M = 0.97.

Figure 10. Wing section normal-force coefficients for orifice rows 1 and 3.

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16. Abstract

Wing pressure distributions obtained in flight with flush orifice and external tubing orifice installations for Mach numbers from 0.50 to 0.97 are compared. The procedure used to install the external tubing orifice is discussed. The results indicate that external tubing orifice installations can give useful results.

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